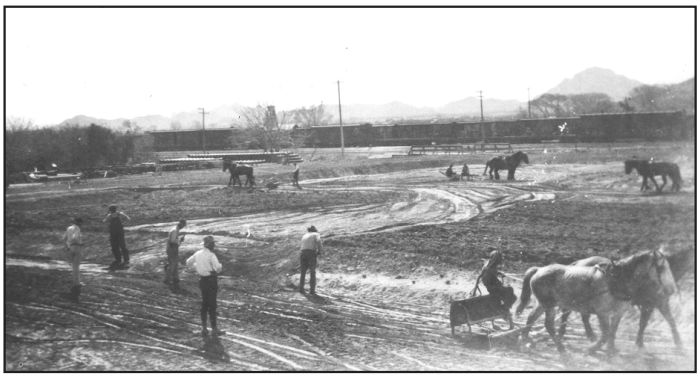
Water-resource planning has always been a complex puzzle. How best to fit the pieces together will need to be continually reassessed in order to achieve long-term sustainability.

CHAPTER TWO

A COMMUNITY CREATES A DEMAND

In 2000, Tucson Water celebrated its 100th anniversary as a municipally owned and operated water utility. As Tucson Water works toward securing the community's water-resource future, much can be learned from the past since the current issues regarding resource limitation are not new. From those times when the local economy was rural and dominated by agriculture to today's technologically driven urban culture, the local inhabitants have had to contend periodically with the limited availability of water resources. Each time the community has approached its resource limits, it has managed to move beyond these constraints to periods of renewed growth.



New Reservoir for Plant 1 - *Leveling and grading for a new reservoir at 17th Street and Osborne Avenue, circa 1914.*

While growth has resulted in benefits, it has also created many water-resource management challenges. With increasing development, significant ground-water level declines have occurred. These declines contributed to the disappearance of natural perennial surface-water flows along certain reaches of the Santa Cruz River and some of its tributaries. The community's increasing demand for additional ground-water supply has changed the natural environment within the urban area, along riparian corridors, and in the surrounding desert. Though technology has increased the availability of accessible water resources, it has not yielded inexhaustible sources of supply. With current development pressures, the community is again approaching the limits of its available water resources and will require additional supplies to satisfy projected demand.

Local history reveals that the community's current water supply concerns resemble those of a century ago. Water management in the Southwest can be characterized as a recurring pattern of shortfalls followed by technological advances that helped to provide, at least for a time, an adequate water supply for a growing community. Like many times before, the community again has to assess a range of water supply alternatives in order to ensure that it has a sustainable future.

PRIOR TO 1880: LIFE ALONG THE SANTA CRUZ RIVER

Prehistoric Native American hunters visited the Santa Cruz River near Sentinel Peak ("A" Mountain) as early as 9500 B.C. Archaeological investigations have unearthed evidence of canal irrigation built by predecessors of the Hohokam culture as early as 1000 B.C. The Hohokam settled along the river and grew crops from 650 to 1450 A.D. The Hohokam's network of canals was used to divert river flows to irrigate crops and their sophisticated design demonstrated a keen engineering knowledge. Their activities were so significant that they altered the river's natural course (Logan, 2002). The Hohokam's water diversions undoubtedly reduced the availability of surface-water flows for other inhabitants who lived further downstream. Intensive farming along the Santa Cruz River by the Hohokam peaked between 900 and 1300 A.D., but it was still practiced by the Tohono O'odham when Father Eusebio Kino visited the area in 1694 (Betancourt, 2004; Logan, 2002).

Human Figurine *–A Cienega Phase (800 B.C. to 150 A.D.) artifact found at the Sweetwater Recharge Facilities.*

Many different cultures have lived near the Santa Cruz River-Native Americans, Spanish colonizers, Mexicans, and finally settlers from the United States and its territories. Spanish missionaries established the San Agustín Mission and Convento village in the mid-1700s just west of present-day downtown Tucson. A Spanish military settlement developed at the Presidio (1775) and the arrival of Spanish settlers stimulated agriculture, ranching, and mining. Over time, these activities resulted in the over-utilization of surface water. An American encampment was later established at Camp (Fort) Lowell (1866) concurrent with a large influx of new settlers into the area. As growth occurred, the surface-water resource upon which the community largely depended continued to be over-utilized and became a constraining factor in the area's development (Logan, 2002).

POST-1880 TO WORLD WAR II: A LESSENING STREAM

By the early 1880s, Tucsonans could no longer rely on surface-water flows from the Santa Cruz River to satisfy their increasing need for water. Water-resource depletion was in full swing. Surface water was diverted for crops, milling operations, livestock, recreational lakes, and mining. The cumulative effects of overgrazing, increasing stream

flow diversions, climatic changes, and the occurrence of high-magnitude floods contributed to further channel erosion, alteration, and gully formation (Logan, 2002).

The arrival of the railroad in the 1880s signaled the beginning of the modern age. Steam-powered water pumps enabled technological advances in water delivery systems that could satisfy increasing water demand. In 1882, the Tucson Water Company, then a privately owned entity, diverted surface water at Valencia Road through a distribution system made of redwood flumes. By the 1890s, the modest system took on the more modern aspects of a water provider as the company constructed its first wells. These wells were dug to about a 20-foot depth and a pumping plant, consisting of a steam-powered pump set at land surface, used suction to withdraw shallow ground water (Logan, 2002).

A frontier and profit-minded ethic resulted in the monopolization of water which in turn led to intense friction within the community (Schaedler and Othmer, 1999). Conflicts over water eventually led to the creation of surface-water and ground-water laws. Apart from "royal decrees and priestly interventions," the earliest law was the doctrine of prior appropriation that was instituted in territorial Arizona in 1864 (Lewis, 2004). Under prior appropriation, landowners who were among the first to file surface-water claims were given a higher priority right. In essence, "first in time" came to mean "first in right." This prioritization of rights made it increasingly difficult for subsequent surface-water claimants to obtain rights to water regardless of the potential benefits that later, lower priority right-holders might offer the community.

The City of Tucson purchased the Tucson Water Company in 1900. In the early 1900s, Tucson Water had a service area population of about 8,000 and provided service through 40 miles of networked water pipelines (Logan, 2002; Baker, 2000). By 1910, all of the water flowing in the Santa Cruz River near downtown Tucson was being diverted for agricultural or municipal uses (Water Resources Research Center, 1999). Policymakers within the City recognized that with continued development, additional water resources would be needed to support the growing community.

Other communities in the Southwest also saw the need for additional future supply. The United States Congress authorized the Colorado River Compact in 1922 which enabled river basin states like Arizona to seek allocations from the Colorado River. Congress subsequently passed the 1928 Boulder Canyon Project Act assuring Arizona and other western states a future water supply from the Colorado River.

High-powered "deep-well" turbine pumps were introduced in the early 1920s and replaced the suction-lift pumps which could only withdraw ground water from shallow depths. This major technological advance provided water users with the ability to utilize ground water as a major source of supply (Driscoll, 1986; Baker, 2000). This innovation enabled Tucson Water and other ground-water users in the area to pump deeper, previously inaccessible ground water. In time, ground water became the only reliable municipal supply source.

Wrapping Pipe - *Much of the work needed to prepare pipe for installation was done by hand, circa 1940.*

Records from wells located along the Santa Cruz River indicate that prior to the early 1920s, there had been negligible change in ground-water levels and that even by 1930, only a relatively small area showed any significant drop in the water table (Schwalen and Shaw, 1957). By 1940, however, water level declines indicated that ground water was being withdrawn in certain areas at a rate greater than natural replenishment. Perennial surface-water flow that persisted in reaches of the Santa Cruz River around Martinez Hill and "A" Mountain vanished by the onset of World War II (Betancourt, 2003).

WORLD WAR II TO 2000: THE COMMUNITY EXPANDS

Tucson's post-depression years were ones of growth and prosperity. The community was gaining a reputation as a welcome place of respite for people who came from areas with colder winter climates. In addition, World War II brought soldiers and their families to Davis-Monthan Air Force Base. The population in the Tucson area began to grow and with that growth came an increasing thirst for water which was satisfied through increased ground-water pumping.

This increasing dependence on ground water created widespread ground-water level declines which were documented in the Tucson region by the late 1940s (Davidson, 1973). The largest historical water-level declines have mainly occurred since the late 1940s and the rate of decline accelerated in the metropolitan area during the subsequent 50 years (City of Tucson, USGS, and ADWR, 1998; Schwalen and Shaw, 1957).

Arizona's pursuit of additional water resources intensified in the 1940s. In 1944, the Arizona legislature finally ratified the 1922 Colorado River Compact to address anticipated population growth and to provide a renewable water supply to offset ground-water pumping. The Boulder Canyon Project Act of 1928 established the State's annual allocation of 2.8 million acre-feet of Colorado River water. However, many decades of political maneuvering were required at the federal level before the physical means to convey Colorado River water to central Arizona would become a reality.

Agricultural water use was greater than municipal use in the Tucson region during the 1950s, but some members of the community were able to see that this could change. Schwalen and Shaw (1957) noted that if metropolitan Tucson continued to grow at its

then current rate, water would have to be diverted from agricultural use to meet future municipal water demand; otherwise, new sources would have to be tapped. In fact, both eventually occurred.

As the City of Tucson began to expand in the early 1950s, private water companies were purchased by Tucson Water. Since that time, system acquisitions have continued to occur. The City also purchased and retired over 22,500 acres of farmland in Avra Valley in the 1970s and 1980s. These farm purchases secured legal rights to withdraw ground water that had been previously used to irrigate crops. These purchases provided the City of Tucson with the means to preserve local ground water for future municipal use. Throughout this period, Tucson Water was totally dependent on ground water as its sole source for municipal supply. The regional aquifers were increasingly overdrafted due to the cumulative pumping of agriculture, mining, and the growing urban area. Tucson Water's efforts to keep pace with continued growth were particularly challenging in the 1970s when well construction had to be accelerated to keep up with increasing water demand.

Having long recognized the local need for additional water supplies, the City of Tucson submitted a letter of intent to the Central Arizona Water Conservation District (CAWCD) in 1975 to take 100,000 acre-feet of Colorado River water annually through the Central Arizona Project (City of Tucson, 1975). The City of Tucson's annual Central Arizona Project allocation has changed through the years and is currently 135,966 acre-feet.

An environmental consciousness grew nationwide in the 1970s and with it a conservation ethic took root in the Tucson area. Tucson Water's *Beat the Peak* Program was established in 1977 and helped Tucson Water control peak demand and delay costly water system expansions. Although it began as a program to manage daily "peaks" in the water system during the summer, Tucson's residents embraced it as a demand management measure with a conservation emphasis. It became the foundation upon which subsequent conservation programs developed. During this time, Tucson Water implemented an "increasing block" rate structure that provided customers with an economic incentive to use water more efficiently. As Tucson's environmental ethic further evolved, there was a gradual change in landscape preferences and a concerted community desire to conserve water.

This environmental ethic also prompted water-quality as well as water-quantity concerns at national and state levels. These concerns resulted in the establishment of federal and state agencies such as the U.S. Environmental Protection Agency (EPA) in 1970, the Arizona Department of Water Resources (ADWR) in 1980, and the Arizona Department of Environmental Quality (ADEQ) in 1986. ADWR was formed to administer the 1980 Groundwater Management Act. This Act is a compendium of complex regulations particularly aimed at managing ground-water resources in designated Active Management Areas within the State. This Act also established a goal of achieving safe yield in the Tucson Active Management Area (Tucson AMA) by the year 2025. The Tucson AMA is shown in Figure 2-1.

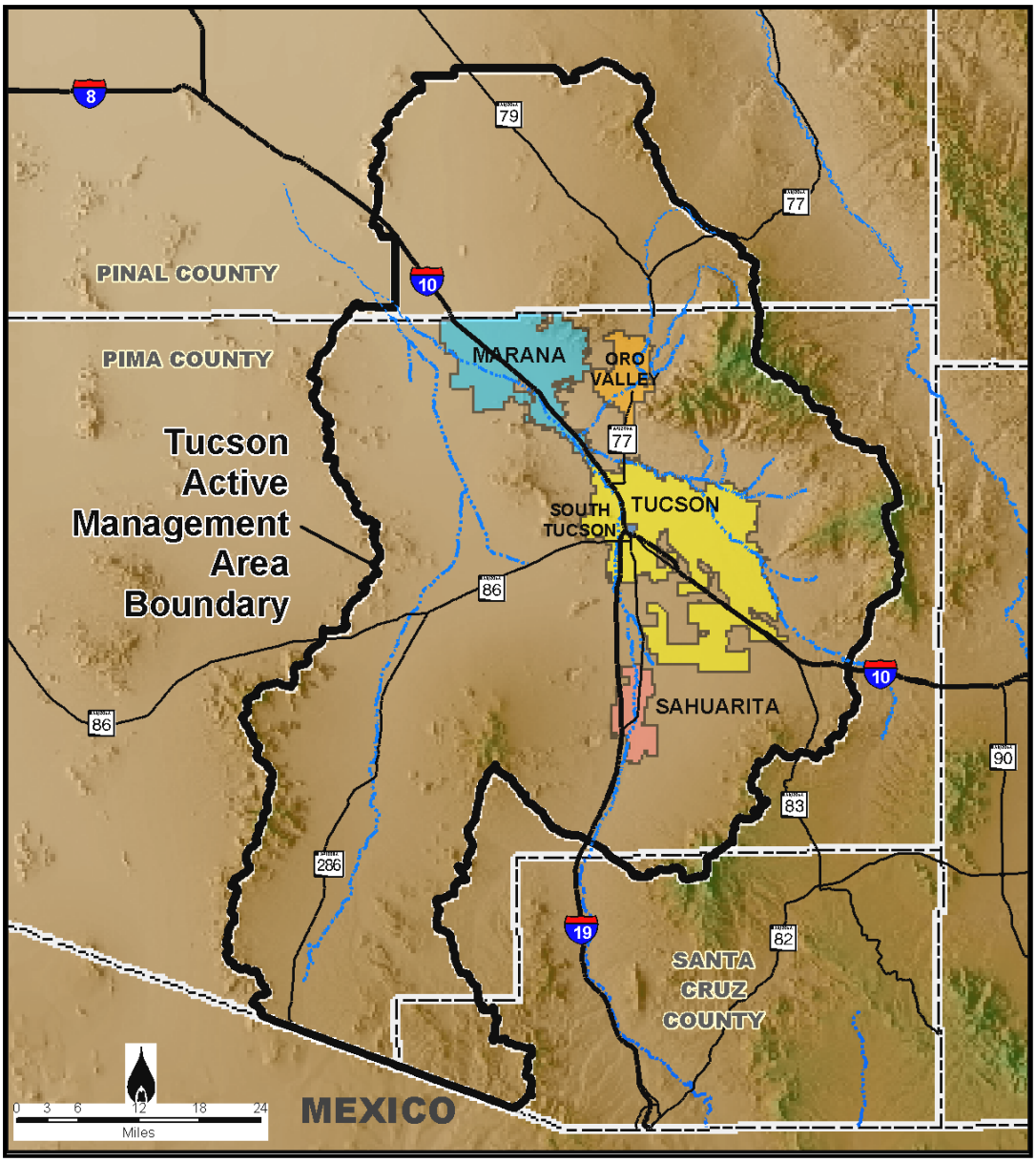


Figure 2-1: Boundary of the Tucson Active Management Area.

As shown in Figure 2-2, water use in the Tucson AMA has changed over time. Industrial and agricultural operations in the greater Tucson region reached peak production in the 1970s. After 1975, agricultural water use in the Tucson AMA dropped significantly while industrial use has remained relatively constant. Since 1940, municipal water use has increased and in the mid-1980s replaced agriculture as the largest water-use sector in the Tucson AMA. In 2000, overall water use in the Tucson AMA was approximately 320,000 acre-feet with municipal water providers accounting for about half of the total. For more information about the region's other water providers and users, see Appendix A: *Other Water Users in the Region.*

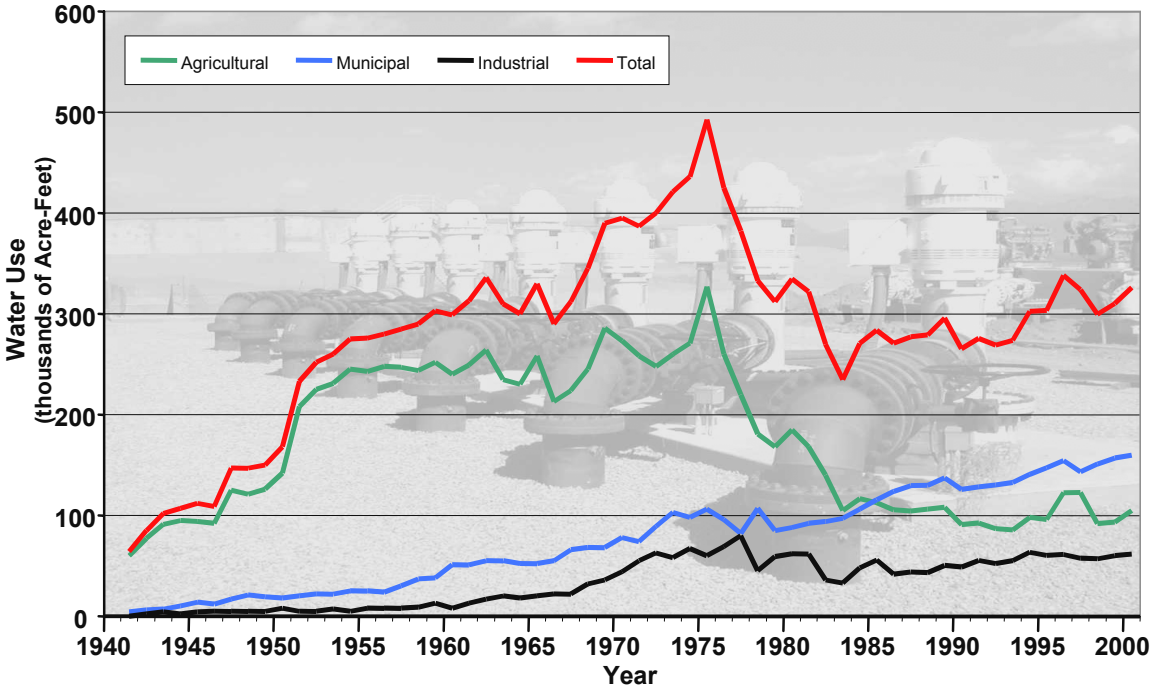


Figure 2-2: Historical Water Use in the Tucson AMA by Sector: 1941-2000.

By the 1980s, water-resource management in the Tucson area had become more challenging. It was increasingly recognized that ground water could no longer be relied on as the sole source for municipal supply. Ground-water levels were declining at an accelerated rate and measurable land subsidence was being documented. In 1984, Tucson Water was one of the first water utilities in the western United States to develop a tertiary wastewater treatment and delivery system. This system produces reclaimed water for urban irrigation and industrial use to conserve ground water for higher quality uses and to reduce ground-water pumping. Plans also were in place to utilize imported Colorado River water via the Central Arizona Project by 1992 to ensure the community would have a renewable source of supply to sustain its future.

An assumption of *Tucson Water Resources Plan 1990-2100* was that Tucson Water would treat and convey (wheel) the Central Arizona Project allocations of smaller water providers to their respective service areas. These providers would in turn deliver the water to their customers. By 1989, the Utility's service area population had grown to about 570,000 (CH2M Hill, 1989). Colorado River water and effluent, the region's only available renewable water resources, were to become primary sources of water supply. Ground water was to be utilized as a backup source and its use would be reduced to a more sustainable level that would allow the aquifer to stabilize over time. It was envisioned that effluent would become an increasingly important source of supply and would augment the ground-water system.

Tucson Water began direct deliveries of treated Colorado River water to portions of its service area in 1992. Direct delivery of treated Colorado River water did not include

recharge as part of the treatment process. From 1992 to 1994, water-quality issues arose that were traced to the pH level of the new source water which reacted with old water mains in the potable distribution system and in customer plumbing. Contrary to commonly held belief, the problems were not related to the higher mineral content of Colorado River water. Tucson's Mayor and Council directed Tucson Water in 1994 to return to ground water as the sole source of supply until water-quality issues could be resolved. Subsequent passage of a citizen's initiative in 1995 effectively prevented Tucson Water from directly delivering Colorado River water to customers in its service area.

In response to these developments, Tucson Water evaluated other options for utilizing Colorado River water that would comply with the citizen's initiative. The Utility developed the Central Avra Valley Storage and Recovery Project (CAVSARP), a large recharge and recovery facility in Avra Valley, to provide a blend of native ground water and Colorado River water. Customer taste tests were conducted as part of the *At the Tap Program* initiated in 1997. The program showed that the public would accept the taste of a 50/50 blend of ground water and Colorado River water.

At the Tap **–** *Extensive research and taste tests were conducted to prepare for the use of Colorado River water, 1997.*

Tucson Water began deliveries of the blended water in 2001. Colorado River water is diverted from the Central Arizona Project and is conveyed to 330 acres of water-spreading infiltration basins at CAVSARP. Colorado River water infiltrates through the basin bottoms and percolates downward through hundreds of feet of sediments to the water table. The percolating water benefits from natural filtration and treatment until it recharges the aquifer and mixes with ground water. Supply wells located nearby recover (pump) a blend of Colorado River water and ground water for municipal supply. CAVSARP is designed to deliver about 60,000 acre-feet of blended water to customers per year. The facility allows Tucson Water to cut back on ground-water pumping in the metropolitan area and to reduce the community's dependence on ground water for municipal supply.

Total water production by municipal water providers in the Tucson AMA was about 160,000 acre-feet in 2000. Of this total, Tucson Water supplied 128,521 acre-feet of water (76 percent) to a service area population of 638,936. As shown on Figure 2-3, Tucson Water is by far the largest water provider in the region. The next largest water providers were the Metropolitan Domestic Water Improvement District (6 percent) and the Town of Oro Valley (5 percent).

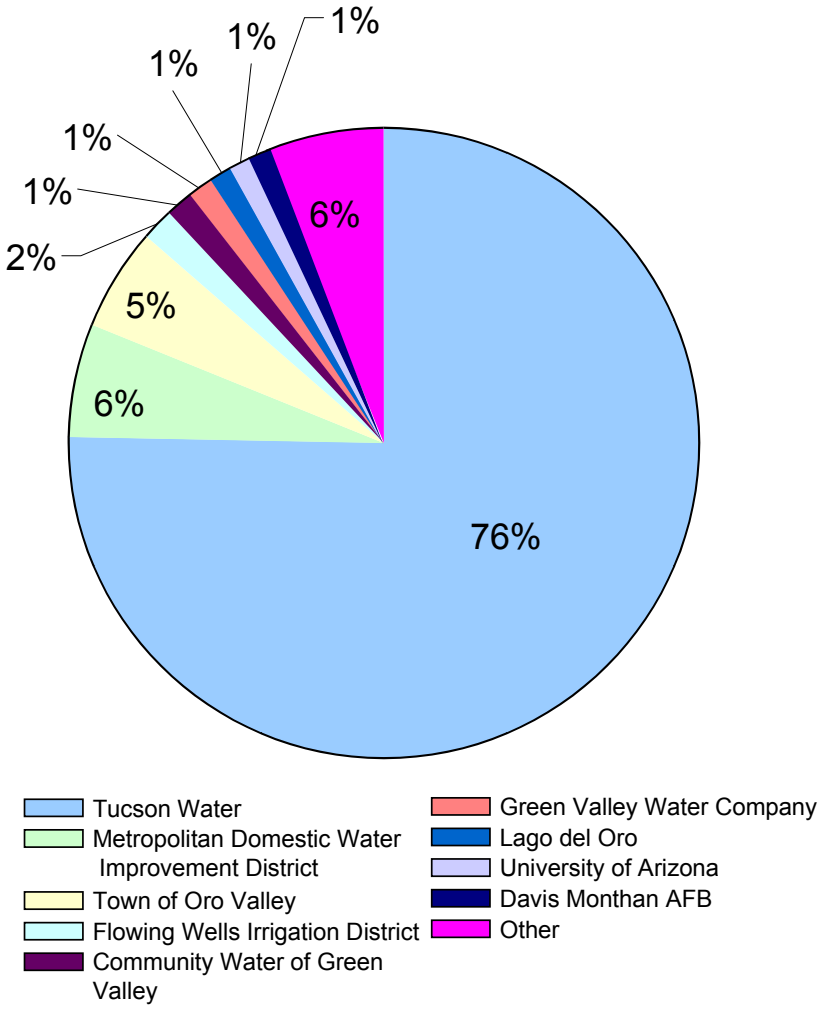


Figure 2-3: Total Water Production by Municipal Water Providers in the Tucson AMA in 2000.

PLANNING FOR A SUSTAINABLE FUTURE

Tucson Water currently has 4,300 miles of pipelines that convey potable and reclaimed water to customers over a 300 square-mile service area. Tucson Water has diversified its use of water resources to include not only ground water but also Colorado River water and reclaimed water. Tucson Water will ensure a sustainable water future within its service area by continuing to reduce the community's reliance on ground water while working toward maximizing the use of its renewable water resources.

Local history shows that competing for additional sources of supply, taking advantage of new technological innovations, contending with droughts, and engaging in water rights and policy disputes are not new. These issues will continue to occur in some form and will require different approaches to address them.

There is already a shift from the traditional approach to water development where the need for new water supplies was satisfied by simply constructing new wells and pipelines to meet localized demands. Problems associated with regional ground-water overdraft and the resulting need to transition to renewable water supplies have made it necessary for water-resource planning to become more sophisticated. The marginal cost of growth will be increasingly placed on new development instead of on the shoulders of existing ratepayers. The new planning approach requires that the service area be managed and expanded as an integrated system.

Addressing concerns over the quality of available supplies, public perception of that quality, and associated customer preferences has become a primary focus in recent years. The current water-resource challenge is to secure adequate water supplies while providing water that meets customer expectations in terms of quality and cost. This is one of the greatest challenges currently facing the Utility and the community.

There is also an increasing awareness of the community's environmental values and efforts to protect and in some cases enhance the riparian corridors and wildlife habitats in surrounding areas. In the past, water-resource development and environmental initiatives have often pursued goals that were in conflict. Tucson Water, in concert with other City of Tucson departments and outside agencies, is exploring win-win opportunities where managing the community's water resources and enhancing local environmental values are compatible. The City has set aside a portion of its effluent supply (Conservation Effluent Pool) to support the development of riparian habitat projects. The Utility's Sweetwater Wetlands, a wastewater treatment facility, is an example of how riparian enhancement and water management can complement each other.

Finally, there is a growing recognition that greater cooperation is needed among Tucson AMA water providers in order to meet the challenges that lie ahead. Significant steps have been taken in this direction in recent years. As available water resources become more limited due to continuing growth, new opportunities to cooperate in acquiring and managing these resources may arise. It is highly probable that statewide competition for new supplies will increase as they become available, and it may prove mutually beneficial if the local water providers work together to augment existing supplies with a common strategy and a unified voice.

Proactive planning will help the community prosper. Growth, annexations of unincorporated areas, purchases of small water providers, acquisitions of additional water resources, changes to City policies, meeting increasingly stringent water-quality standards, and cooperation amongst local water providers are all pieces of the water-resource puzzle. How the pieces fit together will have to be continually reassessed in order to ensure that the community's goal of long-term sustainability can be achieved.